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THE ECONOMIC AND SOCIAL ASPECTS OF SANITARY LANDFILL SITE SELECTION

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October 31, 1972

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FOREWORD

This is the third of three technical reports issued to describe preliminary investigations undertaken as part of the research effort of Contract NAS-9-12646 entitled "Application of Remote Sensing".

The final report of this investigation will be issued January 10, 1973. It will describe the aerial photography used, the methods of analysis, and case studies for the location of potential sites for sanitary landfills in Harris County and four other counties adjoining the greater Houston metropolitan area.

The first report in this series* discussed in general terms the factors affecting site selection, especially the importance of the physical characteristics of the land on landfill location.

The second report** discussed the physical features peculiar to an 18 county region centered around Houston and known as the Houston Area Test Site (HATS).

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October 31, 1972

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*"Factors Concerned With Sanitary Landfill Site Selection: General Discussion" (August 31, 1972).

**"Regulatory Standards and Natural Characteristics Applicable to HATS" (September 30, 1972).

CONTENTS

I. INTRODUCTION

Disposing of solid wastes in a sanitary landfill involves depositing the refuse in a natural or man-made depression or trench, compacting it to the smallest practical volume, and covering it at the close of each day with a layer of compacted earth. Well planned and properly operated landfills are thought by many people to be the most economical method of solid waste disposal. Aside from the cost of the land on which the landfill is located, the capital investment is small compared to other methods of disposal. Frequently the land cost is small because the operation essentially reclaims otherwise useless land. When properly operated, sanitary landfills cause almost no air or water pollution.

Many factors are involved in the selection of suitable sites for landfills. Among these factors the economic considerations and the problems of social acceptance are of paramount importance. These are relatively more intangible than the natural or physical requirements, yet are worthy of careful attention particularly before the actual landfilling operations begin.

Until approximately the mid 1950's the disposal of solid wastes was usually carried out in a somewhat haphazard manner. Very little attention was given to planning of any sort. Cities thought only of immediate needs because there was no difficulty in finding new and convenient disposal sites. In the past twenty-five years there has been an enormous rise in waste generation, likewise a large increase in population. Dumping in random fashion has been replaced by careful engineering and economic study to plan for present and future disposal needs in such a way as to not degrade the environment. Today many authorities recognize sanitary landfilling to be the most important and most economical method of disposal of solid waste (1).

A survey by Keep America Beautiful, Inc. found that there was a close correlation between a nation's standard of living and the amount of solid waste it produces. According to the 1968 survey the United States annually produces about 1800 pounds of solid waste per capita. Other representative countries and their quantities are as follows: Canada with 1,000 pounds; The Netherlands with 800 pounds; England with 500 pounds; and India with 200 pounds (2). In the U. S. the amount of solid waste generated per capita per day has increased from 2.75 pounds in 1920 to 5.3 pounds in 1968 and is projected to be 8 pounds by 1980 (3).

This report discusses the economic and social aspects of sanitary landfill site selection. Particular emphasis will be given to those things which can be seen or inferred from small scale aerial photography.

II. ECONOMIC CONSIDERATIONS

To be successful, that is, economical as well as practicable, a sanitary landfill must be carefully planned as to location and scope of activity at each site. This discussion will treat only those factors which pertain to initial site selection, recognizing that in some instances decisions regarding later operational methods may have considerable influence. When beginning initially the following items all have a bearing on the choice of site: population of city, density of city space, physical characteristics of land, scarcity of land, accessibility of land, haul distance, availability of cover material, capacity of site, land cost, predevelopment of site, and possible operational problems in wet weather.

The determination of land cost in a landfill operation presents some complex questions. Theoretically, the cost of land should be the initial cost less the estimated value to be realized from sale of the land at some future date. This net cost can then be apportioned to find an annual rental figure. The future date may be as far away as 15 to 20 years, i.e., the time needed for the land to completely settle and the waste material to decay after the filling is completed. Future receipts for usable land could be discounted over a shorter period of time, assuming that the major constraint on the use of landfill product is settling rather than gas emission. This is another area in which more examination is needed before the cost considerations are fully realized (1).

A. Haul Distance.

In planning for and locating a sanitary landfill the most important economic factor is usually haul distance. From an operational viewpoint the most inexpensive landfill site would be one located as close as possible to the population center of the collected solid waste. However, as cities grow in population, the haul distance to vacant land in outlying areas becomes longer and longer if no landfill sites have been reserved before development of the suburbs. The economic haul distance will vary from city to city depending upon capacity of collection vehicles, method of collection, salaries of different types of workers, density of city streets, etc.

Haul distance directly affects the collection operation because of its relation to unproductive collection time. The longer the distance to the disposal site, the less time available for solid waste collection. Location of pickup service, whether from the front curb or at the rear of the house also directly affects the unproductive collection time.

Huebner and Fenn noted that transfer stations should be considered for haul distances greater than 20 miles (4). In all large cities, this situation should be common and the need for transfer stations ought to be evaluated. For example, in Los Angeles County, the Sanitation Districts have an elaborate system of transfer stations so that relatively few sanitary landfills serve more than 50 cities and a large unincorporated county area (5). Much greater distances have been investigated in feasibility studies of possible rail transport systems for solid wastes (6).

The following examples illustrate the situations where transfer stations are not needed since the haul distances are less than approximately 20 miles. In the Des Moines area concentric circles from the total study area waste centroid were drawn at 2, 4, 6, 8, and 10 miles (7). Two metropolitan sites were recommended approximately 9 miles away, one to the northeast and one to the southwest. Quon, Martens, and Tanaka studied refuse collection for Wards 13 and 29 in Chicago which were about 6 miles from the disposal site (8). In a different study in the north suburban area of Chicago, a limit on average one-way haul distance of 24 miles was set for the cities (9). The solid waste collection area ranged from Highland Park southward approximately 18 miles to Skokie and 12 miles west to Mt. Prospect.

In summary, haul distances vary generally with the city population and an upper limit of 20-25 miles is usually set as the distance at which transfer stations may be needed.

B. Accessibility of Land.

This becomes an economic factor in terms of the need to build an access road to the landfill site. The access road to the site should be an all-weather hard surface road with proper drainage. On site the roads should be of a semi-permanent all weather type. Usually a vehicle turn-around area is needed. Whenever possible provision should be made for alternate routes to the landfill site from existing arterial roads to minimize the interference that may occur as occasional road maintenance is performed.

C. Availability of Cover Material.

As discussed in the first report of this series the type of earth to be used for cover material is different from that needed for the base layer beneath the landfill. While clay is desirable for the base, sandy loam is the most suitable cover material. It is more economical to excavate material for cover on site than to haul it in, even from adjacent property.

D. Expected Capacity of Site.

The quantity of land over a given number of years required for a landfill or the length of time a known amount of land can be used for landfilling may be estimated fairly accurately once several things are known. The depth available for filling is of primary importance and depends on the highest level of ground water. The types and quantities of refuse going into the fill depend on the nature of the industries or agri-business activities in the city. The in-place density after compaction must also be determined before the site capacity can be estimated.

Volume requirements for sanitary landfills vary from city to city and from region to region in the country. For example, Fresno, California, has much more volume from animal wastes and crop residues added to its municipal solid waste than the usual city ratio since the region is highly agrarian (10). The 1968 population of 312,000 averaged 1.385 tons of solid waste per person/year. These figures are expected to increase by the year

2000 to a population of 1,529,000 and an average of 1.57 tons of refuse/person/year. This contrasts with the 1964 north suburban Chicago area average of 0.75 tons/person/year and the 1985 projection which indicates the same amount (9). In other units the suburban Chicago design volume of 4.0 cubic yards/person/year was estimated from a 2.45 cubic yards/person/year basis, but the latter figure did not account for reduced leaf burning and the need for more frequent and complete collection service. The Texas State Health Department suggests a smaller volume: "As a rough rule of thumb, however, about 7 acre-feet (11,300 cubic yards) per 10,000 population per year is frequently used." (11) This averages 1.13 cubic yards/person/year, which is lower than the 4.0 figure for the suburban Chicago region. The Texas standard may have been determined from a base which did not adequately account for all waste inputs. It may be too conservative and perhaps should be re-evaluated.

Another site capacity parameter is the 8 hour working day versus the 24 hour continuous operation which would affect the pounds of solid waste handled per day (11). The time period for the use of the landfill until completely utilized would certainly be influenced by the hours in operation. The noise problems associated with haul trucks could eliminate collections in residential areas at night, but commercial and industrial solid waste could be collected and hauled day or night. In fact, lost time due to traffic congestion would be markedly reduced by night collection and hauling.

The following example summarizes the importance of the assumptions entering into the site capacity evaluation.

1. Population = 10,000
2. Collection rate/capita (assume) = 5 lb./day

   Collection rate/capita/year = 5 lb./capita/day x 365 day/year = 1,825 lb./capita/year
3. City collection rate = 1,825 lb./capita/year x 10,000 persons = 18,250,000 lb./year
4. Solid waste compaction density (assume)

   = 1,000 lb./cubic yd. (in-place and with careful packing)

$$\text{Volume} = \frac{18{,}250{,}000 \text{ lb./year}}{1{,}000 \text{ lb./cubic yd.}} = 18{,}250 \text{ cubic yd./yr.}$$

$$\text{Volume} = \frac{18{,}250 \text{ cubic yd./year} \times (3 \text{ ft./yd})^3}{43{,}560 \text{ sq. ft./acre}}$$

$$= 11.3 \text{ acre-ft./year}$$

5. Alternate solid waste compaction density (assume)

   = 600 lb./cubic yd. (in-place and with poor packing)

   Volume = 18.9 acre-ft./year
6. Ratio of solid waste to cover soil (assume) = 4/1
7. Volume of cover soil required:

Compaction density	Cover Soil Volume
1,000 lb./cubic yd.	2.83 acre-ft./year
600 lb./cubic yd.	4.73 acre-ft./year

Note that the two compaction densities used in the previous example bracket the 2.45 cubic yd./capita/yr. rate reported for the suburban Chicago area:

$$\frac{1{,}825 \text{ lb./capita/yr.}}{1{,}000 \text{ lb./cubic yd.}} = 1.8 \text{ cubic yd./capita/yr.}$$

and

$$\frac{1{,}825 \text{ lb./capita/yr.}}{600 \text{ lb./cubic yd.}} = 3.0 \text{ cubic yd./capita/yr.}$$

Also, note that Brunner and Keller (12) indicate a range for the ratio of solid waste to soil cover material:

$$\frac{3}{1} < \frac{\text{Solid waste}}{\text{Cover material}} < \frac{4}{1}$$

The amount of cover soil depends on cover thickness and on the cell configuration used in the landfill. This is a very important point regarding site evaluation in terms of selecting a site which has soil well suited for daily cover material. Workability of the soil is of primary concern in locating cover material. Clay is not a workable soil in terms of spreading easily for the daily six inch cover layer.

Raw refuse is estimated to weigh about 150 pounds per cubic yard. One ton of refuse, as collected, occupies about 13.3 cubic yards. When placed in a landfill ready to be covered, the refuse occupies approximately 2.22 cubic yards or about 1/6 the collected volume (2).

E. Land Costs.

The amount of land required can be estimated from the expected volume of refuse if the depth of the landfill is known. Cell depth is defined as the thickness of solid waste layer measured perpendicular to the equipment working slope. While 8 feet is recommended as a maximum single cell depth since excessive settlement and surface cracking may occur with deeper cells, cell depths of various landfills range from 2 to 15 feet (13). Although cell depth is not the same as the vertical depth to the bottom of the landfill, when combined with the layer thickness of cover, it does provide a way of estimating the magnitude of landfill depth. The total land area is the volume of solid waste divided by the expected landfill depth. Additional land for working room, storage of soil cover, and equipment access and storage will have to be purchased.

Although land values can change fairly quickly, the land cost should be considered a major item in the site selection process. The range in costs from site to site can be huge. For example, purchase of land for landfilling in the Los Angeles area in the late 1950's cost approximately $1,000 per acre contrasted with purchase of land at $12,000 per acre in Kansas City, Kansas, in the mid 1960's (4). As land costs are so variable, and dependent upon local conditions, each site should be appraised by several real estate and/or tax evaluation people.

In assessing land cost some effort should be made to determine if the land value might be expected to have increased or decreased by the time the landfilling operation has been completed.

Other cost aspects of landfilling such as the operating cost (e.g., useful lifetime of 5 years or 10,000 operating hours for landfill equipment (12)) will not be covered here since operating cost has little relationship to site selection. Suffice it to say

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that 80 to 90 percent of the total operational cost is attributable to collection and transportation and only 10 to 20 percent is involved with the actual landfilling operations (14).

The planning and study for site selection should include the analysis of possible economic liabilities arising from improper site selection or sloppy operation. The economic losses resulting from improper solid waste handling are indirect or hidden but include such items as depreciated property values, air and water pollution, fire and rodent damage, medical bills, and litigation expenses.

The total cost of a landfill is the sum of the estimated net land cost, the site development cost, equipment cost, operating expense, and the landscaping and maintenance costs, both during and following completion of the landfilling operations. Considered from this overall long-range point of view the cost of the land for the site is a small part of the total undertaking.

The case studies of selection of potential sites in the greater Houston metropolitan area did not investigate land costs, although this would be a relatively simple extension of the work done in this investigation.

F. Pre-development for Landfill Use.

Pre-development costs will vary depending upon the physical characteristics of the site. This work is oftentimes called site preparation, and how well it is done may make the difference between a successful landfill and a costly unsatisfactory operation. The following list does not include all of the site preparation considerations, only those related to the economics of initial site selection.

1. Presence of or need to provide an all weather access road to the site and all-weather maneuvering roads on site including a turn-around area.
2. Difficulty of obtaining proper drainage, need for dikes or levees.
3. Presence or need to provide screens or fences to prevent paper from being wind blown. A forested strip makes an excellent screen for dust as well as wind blown paper.
4. Extent and difficulty of excavating for proper lift depth and usability of this soil for cover -- also whether or not there is available sufficient space for the storage of the excavated cover material.

G. Future Use.

In general, there are two schools of thought for the future use of sanitary landfill locations after the fills have been completed: (1) use the site as open space, and (2) use it for the construction of facilities. The Solid Waste Management Office, EPA, recommends that completed fills be used solely for open space such as a green area, a recreational area, an agricultural area, or in some cases, in conjunction with open space for the construction of light buildings (4). Other authorities believe that completed landfills can be utilized as sites for high rise buildings, recognizing that settlement and gas evolution will require special designs and more expensive construction techniques. The final development cost of the site following the landfilling is certainly an economic factor that deserves careful attention.

III. SOCIAL CONSIDERATIONS

Proper location for solid waste disposal facilities has been for at least the past two decades a serious and complicated problem for urban communities of all sizes. The most important reasons for this are related to (1) the strong public aversion to the potential nuisances associated with any kind of waste disposal, including traffic, odors, noise, air and water pollution, litter and general unsightliness, and (2) the historic tendency of planning agencies to either ignore the subject, or fail to adequately face up to the long-term needs of growing communities as related to solid waste disposal. For these reasons, many large cities find themselves groping for answers to problems whose complicated requirements are almost untenable, and expediently continuing practices that border upon being intolerable from a public health and nuisance standpoint (15).

As our country becomes more urbanized we can count on there being an ever increasing volume of refuse which needs to be disposed of properly. Generally speaking, it is becoming increasingly difficult to keep existing sites. New sites are becoming more difficult to obtain. Public reaction is mounting against improperly operated refuse disposal sites. A landfill operation of the type that was acceptable in the mid 1950's is not acceptable now. Today there is a need to narrow the gap between what is known to be good practice and what is practiced (16).

Because of past abuses as to dumping one could summarize the position of most home owners with the slogan, "Put your dump elsewhere."

Needless to say, open dumping has no place in modern waste management practice. Besides being a stark affront to even the most rudimentary aesthetics, open dumping constitutes a public health hazard and destroys the land it occupies (1). Disposal of solid wastes is necessary, and it is incumbent upon all associated with sanitary landfilling today to make the activity just as socially acceptable as possible while still maintaining an economic and engineeringly sound operation.

Almost without exception, the public announcement of a new landfill location promptly brings forth public reaction with petitions, newspaper outcries, public hearings, and denouncements by self-seeking politicians. More often than not in these cases, the objectors will have little knowledge of the proposed landfilling operations or the public safeguards.

Property owners near a proposed landfill or transfer station site may be rightfully apprehensive about unsightly collection trucks, illkept crews, dust, litter, and noisy operations, especially at night or early in the morning. The public generally wants convenience and cleanliness, but otherwise does not want to be aware of the solid waste disposal operation.

It is difficult to reduce the problems of solid waste managment to clear-cut scientific or engineering investigations because the economic and political factors are so intertwined and sometimes dominant (14). All who work with social problems are aware of the immense difficulty involved in actually measuring or evaluating a public good such as a landfill. Setting meaningful boundaries that describe, even approximately, areas of public concern is difficult. Attempting to assign costs to environmental quality and the quality of life made possible by the absence of disease involves community value judgment. There are no inherently correct decisions. The need for public acceptance of landfills is forcing more combined planning by social scientists, engineers, and economists.

In the paragraphs which follow the several social considerations that bear upon landfill site selection are discussed. These are listed according to their generally accepted priority.

A. Cover Material and Compaction.

Perhaps the most important factors relative to social consideration are the proper spreading and compaction of refuse in cell layers, usually about two feet in thickness, followed by a daily cover of at least six inches of soil, preferably sandy loam. Proper compaction insures that settlement of the refuse will not be excessive and uneven, permitting passage of insects and rodents and limiting the usefulness of the finished landfill. The daily cover minimizes many socially-undesirable aspects: flies, rodents, blowing litter, odor production, fire hazards, and unsightly appearance (17).

The fly problem is directly related to compaction in that house flies were found to emerge through five feet of <u>uncompacted</u> cover, but a six-inch compacted layer prevented fly emergence (18). Gases produced in a landfill include hydrogen sulfide, methane, nitrogen, carbon dioxide, and hydrogen (13). Fast, continuous coverage of refuse and good compaction should minimize odor problems.

B. Wind Blown Litter and Dust.

Blowing paper waste was the operating problem most commonly mentioned in a survey of landfill practices by the American Society of Civil Engineers (19). This causes a nuisance to nearby property owners, is unsightly, and could be a fire hazard (17). Litter can be contained by the use of: earth banks, natural barriers such as a green belt of trees or high hedge, and fences, both permanent and portable types. Natural barriers, earthen berms and fences around sanitary landfills serve three purposes: obscure the view of the operation from people on the outside, control wind blown paper, and control entry to the landfill site. In site selection aerial photography can be examined to see if any natural barriers are adjacent to a potential site. This could give one site a slight advantage over another which did not have such a natural barrier.

Dry weather dust problems may be controlled by several means, including: sprinkling the working area, light sprinkling of the refuse immediately after placement, planting grass and plants on completed portions of the fill, and access road surface treatment with water, calcium chloride, road oil, or permanent topping. The use of sprinkling water necessitates a nearby water source such as a lake or a well with reservoir. Lakes and reservoirs can be identified from aerial photography although surface water bodies are often more easily detected using infrared photography. The nearby water source should not be allowed to become contaminated by leachate from the landfill.

Surface runoff from the fill should be monitored and channeled into the surface water system downstream of the lake or pond. Protection of ground water is afforded by the impervious seal which should be situated or created beneath the landfill.

C. Fire Protection.

It is a common rule now that no burning should take place at a landfill. Past problems of open burning at dumps have helped to create a bad public image of solid waste disposal techniques and caused the public to accept with voiced skepticism the location of future sanitary landfill sites and the reassurances concerning present day landfill operations. Combustion creates: odors, air pollution, and fire and safety hazards. Accidental fires should be controlled by: a sufficient supply of suitable pressure water with hose, a stockpile of loose soil near the working area of the landfill for immediate cover, and proper fire extinguishers on equipment and in the buildings on site.

D. Site Location with Respect to Residential and Industrial Areas.

When examining photography for potential sites special consideration should be given to selecting sites as far away from residential developments as possible to minimize any adverse effects. In other words, buffer areas between subdivisions and a potential site would be beneficial in public acceptance of a potential site. This procedure is being followed in the study and selection of potential sites for counties in the Houston Area Test Site.

For sites located near industrial parks or factories, the sanitary landfill should not be as unacceptable as near private housing. Therefore, if land costs permit, this land would be preferable over land for a site near a subdivision or apartment complex.

The public is usually apprehensive about possible health, nuisance and safety problems, and with whether or not property values in the immediate neighborhood will depreciate because of the landfill. When a sanitary landfill is properly operated there should not be numerous complaints from nearby property owners. It is unfortunate but true that the image of a properly operated landfill must be upgraded in the mind of the average citizen. The time when operators or agencies responsible for waste disposal could get by with marginal or inadequate methods relying on public apathy to "make up the difference" is gone. Everyone's concern today for environmental quality has replaced the old attitude of indifference, even though the new attitude necessitates a higher cost of operation.

E. Land Usage after Landfill Completion.

One important way to enhance the local public acceptance of a landfill in some specific location would be to have a beneficial purpose planned for the completed landfill and emphasize this goal before the undertaking is ever started. The construction of parks, playgrounds, and golf courses has successfully demonstrated the utilization of completed landfill sites that had acceptable compaction and final cover (13). For instance, in San Diego, California, there has been for some time a sanitary landfill in Arizona Canyon in the city's beautiful and centrally located Balboa Park. Although this landfill is only several hundred feet from very desirable and expensive residential property, the operation is acceptable and the concept is publically accepted because the residents understand that the ultimate result will be the creation of 40 acres more of usable park land (20). Also, there is a landfill inside the city limits of Cedar Rapids, Iowa, and close to residential areas, and yet it arouses no public reaction from the nearby residents. The principal reasons which have been given for the success of the operation are: (1) the meticulous attention given to details which ensure that the fill is truly a sanitary landfill; and (2) the planned filling operation will eventually eliminate a public eyesore, namely, an abandoned quarry occupying 94 acres with the city (21).

In general construction of buildings on finished landfills has been avoided because of ground settlement and gas generation. Methane is the chief gas produced and the danger attendant with its evolution is that it may seep into the understructure of buildings constructed on the site, mix with air, and create the possibility of an explosive hazard. There have been instances where one-story buildings and airport runways for light aircraft have been constructed directly on old sanitary landfills. Two and three story residential construction where the ground level was left open and used for parking has been accomplished. In the Chicago metropolitan area, on a location which formerly was a fill site for rubble from building demolition, a 14-story apartment building was constructed with the main structural support being provided by 50-foot pilings driven to bedrock (22).

The ground settlement situation deserves special attention since studies have indicated that 90 percent of the final settlement will proceed in the initial five years. The remaining settlement occurs over a longer, unspecified time. In Los Angeles sanitary landfills 90-110 feet in depth have settled from 2.5 to 5.5 feet in three years (13). The American Public Works Association reported that the average of the settlements experienced in 58 cities with fill depths varying from 4 to 20 feet was 11 percent after two years (23).

Final grading and settlement maintenance are important to restore the land surface after landfilling. This maintenance usually includes:

1. Sloping the land to conform with area drainage.
2. Grass seeding of the completed landfill to minimize erosion problems.
3. Regrading the surface after settlement to keep proper drainage.
4. Filling in small depressions.

In conclusion, the many social considerations for landfill sites have been outlined and discussed. If the sanitary landfill is planned for a desirable public land usage after completion and if it is properly designed, constructed, operated, and maintained after its completion, the public will have no cause to object to its presence.

IV. CLOSURE

While the sanitary landfill method of solid waste disposal has been widely practiced for many years, its acceptance by the general public is still problematical. Many people fail to understand the difference in a sanitary landfill and a dump and are distrustful that even if there is a difference the older more objectionable operation is what is being proposed, simply identified by a new catch-phrase. This has been the case oftentimes and the public attitude is not without basis.

A well designed and properly operated sanitary landfill can meet the public health standards of any community. Hence "public health" means not only the direct transmission of disease to men and animals and the reservoirs from which these diseases may emerge, but also environment depreciating factors such as odor, visible smoke, gases, dust, noise, wind blown paper, heavy traffic, and unsightly appearance.

Two simple aspects of careful planning and efficient operation that help significantly in gaining public acceptance have to do with appearance. If the site is enclosed by a fence or green belt and the entrance road bends just inside the gate, then the haul trucks quickly diappear from public view. Daily cleaning of paper from fences and ground, both on site and in the immediate neighborhood leading to the site, will go far in removing the "dump" impression from people's minds. Frequent sweeping of dirt and earthen clods from the access roads will lessen considerably the dust nuisance which the public expects to have to tolerate.

Where local governments and operating agencies have adhered to policies of modern methods and excellent housekeeping the aversion attitude of the public has tended to vanish (15).

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